TENDENCIES IN NORTH-SOUTH PREFERENCES IN THE ORIENTATION OF SILKWORM[1]

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The larvae of *Bombyx mori* in a four way choice box execute their magnetic compass heading to spin cocoons and their proportion of movement from east-west axis is equal to either direction of south-north. Additional magnetic field elicited a behaviour in which the larvae totally lost the sense of direction. However, the magnetic influences were not observed on the quantity of silk spun.

Introduction

Animals rely on many sensory cues to orient their movements (Carthy 1951, Edrich 1977, MacGregor 1948, Van Frisch 1950). The magnetic field perception was first observed in birds (Griffin 1944) and it exists in lower organisms also (Brown 1962, Palmer 1963). *Drosophila* prefer to fly within a magnetic field (Wehner and Labhart 1970) and the bees construct their hives depending on geomagnetism (Jong 1980, Martin and Lindauer 1973). Geomagnetism is also pronounced in higher vertebrates and used commonly in homing behaviour (Keeton 1971, Philips and Alder 1978, Yeagley 1947, 1951). Recent studies emphasize the possibility of magnetic materials in animals (Presti and Pettigrew 1980), and the view on "personal magnetism" was expressed from bacteria to man (Maugh 1982).

The present study was designed to investigate geomagnetic influences on the orientation of silkworm in cocoon formation and also the influence of additional magnetic field (AMF) on the orientation of a spinning larva.

Material and Methods

Larvae of silkworm *Bombyx mori* NB_{18} reared in the laboratory were maintained on mulberry leaves. Healthy fifth instar larvae attaining spinning stages were selected for experimentation. Wooden boxes with four arms, each arm measuring $7.6 \times 3.8 \times 10$ cm. were placed with arms facing south, north, east and west directions. The arms were orientated on a flat working table to a desired direction using a compass. One spinning larva was introduced into the centre of the four way choice box.

The box was covered with a transparent cellophane paper to prevent crawling of worms out of the walls of the arms. The box was placed under diffused light for spinning in an undisturbed area.

Induction of magnetic field: Two circular (Helmholtz) coils with 28 cm diameter and a winding length of 80 cm, were used for experiments and the distance between the two coils was 10 cm. Each coil consisted of 1500 turns, which were wound uniformly on an aluminium frame. At a 12 input DC voltage, the current in each Helmholtz coil measured 0.5A, resulting in creating an additional magnetic field 11.8 H. The dissipated power caused no significant rise in temperature to injure the spinning larvae.

Statistical analysis: A Chi-square test was employed to relate the proportion of cocoons spun in the arms facing different directions. Analysis of variance for the differences in

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cocoon weights and correlation regressions were fitted for the relation between weight-length, length-width and width-weight. Statistical analysis was carried out using DCM microsystem 1211.

Results

When a healthy and fully matured fifth instar larva is inserted at the centre of the four-way choice box, the larva wanders and finally migrates to one of the arms and settles there for spinning. Under normal geomagnetic conditions, the direction of migration and orientation seems to be polarized (Table 1). A significant majority of the larvae chose to move to the arms facing north-south axis. When the natural geomagnetic field is cancelled or nullified by the application of electromagnetic field, the north-south axial migration of the larvae is disturbed and the larvae settle haphazardly in the four arms of the choice box (Table 1).

Table 1

Directional preference by the silkworm larva inserted in a four-way choice box

Larval orientation with respect to	X^2 value	Condition of the electro-magnet
South (90), North (86) East (52) and West (56)	16.507*	Off
South-east (29) and South-west (26)	0.666	Off
North-east (27) and North-west (19	4.333	Off
South (49), North (50) East (48) and West (49)	0.650	On
South-east (23) and South-west (24)	0.166	On
North-east (27) and North-west (25)	0.133	On

* highly significant.

Figures in parentheses refer to number of larvae settled in each arm.

When the box is rotated so that the arms face the intermediate directions like south east-south west and north east-north west axis and the larvae are inserted at the centre of the box, the migration and orientation of the larvae becomes jumbled up, and no significant change in their orientation for spinning resulted (Table 1). The electromagnetic field has not altered this behaviour.

Concentration of the larvae in south-north axis of the choice box could be a result of some sort of taxis. The worms prior to cocoon spinning exhibit a characteristic exploratory behaviour in the four-way choice box before they actually settle down for spinning. The navigation of an individual larva in the centre of the choice box to north-south axis is interesting. The larva makes a search, raises its head and rotates itself until it finds the north-south direction. If the larva is left at the mouth of north or south arm, it slowly moves on to find a congenial place in the arm for spinning. If it is left near the mouth of west or east arm, it shows exploratory behaviour and spends a long time crawling. Most of such larvae find the north or south arms when they crawl to the centre of the box. While the behaviour being so in confined larvae, the majority of the unconfined larvae orient their cocoons with the long axis parallel to the north-south axis.

Qualitative parameters like weight, width and length of cocoons showed some degree of dependency on the directional preference (Tables 2 and 3). Weight and width characteristics of cocoons in north arm yielded greater correlation coefficients (r) (Table 3) and the fact obviously shows that the cocoons spun in the arm pointing north-south axis are of good quality.

Discussion

Living organisms are sensitive to fluctuations in geomagnetic fields (Brown 1959, Brown *et* *al.* 1960a, Brown 1962, Keeton *et al.* 1974). The present findings of silkworm movements in a choice chamber indicate that the larvae exhibit geomagnetic orientation during spinning, and the results are similar to those observed in snails and birds (Brown *et al.* 1960b, Visalberghi and Alleva 1979). *Bombyx mori* larvae placed at the centre of the four-way choice box prefer north-south arms to spin their cocoons. This orientation is a result of an exploratory behaviour of the confined larvae. Raising its head, the confined larva rotates itself to find its way into north-south axis. The unconfined larvae orient their cocoons to lie with their long axis parallel to north-south axis.

TABLE 2

LENGTH, WIDTH AND WEIGHT OF COCOONS SPUN IN THE ARMS OF THE FOUR-WAY CHOICE BOX

Arm	Weight* g	Length* cm	Width* cm
South	208.78±28.36	3.3 ±0.18	1.79±0.24
North	196.72±18.51	3.28±0.17	1.77±0.12
East	193.11±14.49	3.26±0.15	1.79±0.13
West	200.39±17.77	3.41±0.17	1.83±0.16

* mean ± SD of 18 observations.

TABLE 3

CORRELATION REGRESSION BETWEEN WEIGHT, WIDTH AND LENGTH OF COCOONS SPUN IN THE ARMS OF THE FOUR-WAY CHOICE BOX (BASED ON THE RAW DATA OF TABLE 2)

Direction	r values Weight/ Length	Weight/ Width	Length/ Width
South	0.284	0.658*	0.374
North	0.511*	0.690*	0.336
East	0.427	0.647*	0.070
West	0.638*	0.585*	0.508*

* Significant at 5%.

The mechanisms by which the larvae end up in the north-south arms of the choice box must be sought in the occurrence of sensory cues delivered by special sense organs situated in the head region. It is usually the dip vector of the earth's field that animals use and probably in the present instance also, the larvae use the same vector to make their choice when they are inserted at the centre of the box. The dip at Bangalore is 13°, with horizontal component being 0.38H and vertical component of 0.088. The abolition of north-south axial migration of the larvae in the additional magnetic field (AMF) further confirms the fact that the larvae are sensitive to the earth's field. Hornet nest pattern (Kisliuk and Ishay 1978) and bee comb building (Martin and Lindauer 1977) are known to be altered by induced magnetic field. North-south seeking magnetotactic response observed in the silkworm could be an orthokinesis. For all such magnetotactic responses the magnetosomes situated in the head region of the larvae might be responsible (Maugh 1982). Although the silkworm is totally domesticated now, it is interesting to note the persistence of orthokinetic responses not influenced by domestication.

The impact of geomagnetic responses in the larvae not only orient the worm to start spinning but also influence the quality of cocoon, adjudged by the cocoons spun by worms oriented north-south axis of the choice box.

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